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14. ABSTRACT

The research objectives of this task are three-fold. The first objective is to predict the unsteady air wake over Navy class ships. A database of important air wake conditions is thus developed which can then be incorporated into a manned flight simulator. The improved simulation environment can then ultimately be used to train pilots and develop shipboard flight envelopes that would otherwise only be developed with expensive at-sea trials with real aircraft, crew and ships. The second objective is to determine the time-varying affect of the air wake generated by a ship on a hovering rotorcraft, in this case the V-22, and vice-versa. This analysis is used to analyze the causes of increased pilot workload at problem landings spots. The third objective is to provide an accurate and efficient design tool to aid in the development of improved air vehicle/ship interface designs for future Navy ships.

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Time Accurate CFD Analysis of Ship Air Wake with Coupled V-22 Flow

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HPC Computer Resource: IBM SP P3 [ASC MSRC], SGI Origin 2000 [ASC MSRC, ARL MSRC]

Research Objective: The research objectives of this task are three-fold. The first objective is to predict the unsteady air wake over Navy class ships. A database of important air wake conditions is thus developed which can then be incorporated into a manned flight simulator. The improved simulation environment can then ultimately be used to train pilots and develop shipboard flight envelopes that would otherwise only be developed with expensive at-sea trials with real aircraft, crew and ships. The second objective is to determine the time-varying affect of the air wake generated by a ship on a hovering rotorcraft, in this case the V-22, and vice-versa. This analysis is used to analyze the causes of increased pilot workload at problem landing spots. The third objective is to provide an accurate and efficient design tool to aid in the development of improved airvehicle/ship interface designs for future Navy ships.

Methodology: The computational fluid dynamics (CFD) code used for this analysis is the CHSSI developed code Cobalt. Cobalt solves the Navier-Stokes equations using a finite-volume algorithm that is cell-centered, second-order accurate in space and time, and was developed for use with unstructured grids. All computations were unsteady, time-accurate calculations due to the highly unsteady nature of the air wake flow field. The V-22 rotors were modeled as actuator disks coupled with the unsteady flow.

Results: The numerical analysis revealed features in the ship air wake that had not been observed before using conventional experimental methods. In the first figure, iso-surfaces of vorticity are used to reveal the pair of deck edge vorticies, a large separated region at the bow, and a set of "bubbles" that are periodically shed from the bow separation. The detection of the periodic shedding from the bow was made possible through animation of the time-accurate computation. In the second figure, surface pressures on a V-22 tiltrotor in hover and on the ship deck show the effects of the coupled rotor wake and ship air wake. Surface oil flow patterns indicated several separation and reattachment lines.

Significance: This work demonstrates the feasibility of computing large, time-accurate CFD simulations for low-speed, highly-separated flows. The primary impact is in reducing the development costs of shipboard flight envelopes. This work could significantly reduce that cost by providing realistic, time-varying air wake models to manned flight simulators. The simulators would then be used to develop the initial flight envelopes in a virtual environment thus reducing the need for expensive at-sea trials. In addition, this work provides a unique opportunity to improve the understanding of ship air wake aerodynamics in general. Finally, the analysis techniques developed here can be used to aid in the design of the flight decks and islands on new ships and thereby address flight operations at the very initial stages of ship design.

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